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Heat Transmission Through Condenser Tubes

R. W. Kimball
N. L. Edson

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Kimball, R.W.
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Condenser Tubes

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HEAT TRANSMISSION THROUGH CONDENSER TUBES

A THESIS

PRESENTED BY

RAYMOND W. KIMBALL

NORMAN L. EDSON

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

HAVING COMPLETED THE PRESCRIBED COURSE OF STUDY IN

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Heat Transmission Through Condenser Tubes.

This series of tests was carried on with the object of determining the rate of heat transmission through condenser tubes for different velocities of cooling water, and for different absolute pressures in the condenser.

The condenser used in the experiment was a Wheeler Surface condenser containing 114 nickel plated, steel tubes. The condenser was round and it was placed horizontal on two pipe stands. The condenser walls are cast iron, 1/2 inch thick. The tubes are 1/2" inside and 5/8" outside diameter and 54-1/2" long. They are secured in the condenser by two brass plates, which are bored to form packing glands for the tube ends. The packing consists of an asbestos, woven string wound around the tube and held in place by a brass bushing. The cooling water is admitted at the end and bottom of the condenser and discharged at the same end, at the top. The inlet and outlet are separated by a partition which extends from the tube plate to the condenser cover. This partition causes the water to flow through the lower 57 tubes, to the rear of the condenser and back through the upper 57 tubes, to the 1-1/2" outlet. The steam enters through a 2" pipe at the top and front of the condenser and the condensed steam is pumped through a 2" pipe from the bottom and rear of the condenser. The vacuum gauge connection is at the top, over the condensed steam discharge.

A 6"×6"×8" Marsh Steam Tank pump is used on the condensed steam. It is located beneath the condenser and discharges into two weighing tanks.

The tanks used for the cooling water are round, steel, and about 1300 pounds capacity. They are on Fairbanks scales and are emptied by a three inch connections in the side at the bottom; the discharge being into a sump used for the pumps. The tanks for the condensed steam are rectangular, steel, and about 900 pounds capacity. They are on scales, similar to those of the cooling water tanks, and they empty into the same sump.

The thermometers were ordinary Fahrenheit thermometers, ranging from 0° to 215°F., with the exception of two, which range from 0° to 400° and a Standard Schaffer & B'Denberg centigrade thermometer, 0° - 100°C.

A Crosby vacuum gauge, No. 500,001, and an ABN. Mercury vacuum gauge, with a range of 18" to 30"; both gauges were connected to the same condenser connection.

In preparation for the experiment, the first thing done was an examination and cleaning of the condenser. A block and tackle was secured to an overhead steam main and to the condenser, all connections to the condenser were loosened, and the condenser lowered to the floor. Two gallons of gasoline were poured into the condenser, blind flanges were fitted to the openings, and the condenser was thoroughly washed out. After this, it was put in place, the proper connections were made to the 2" steam pipe, the 1-1/2" water pipe, and the 1-1/2" discharge to the sewer. Three new connections were made, one 1-1/2" connection to the discharge pipe, which made it possible to discharge the cooling water into the tanks;one 1-1/2" connection to the water supply pipe, making it possible to use the Marsh steam pump to obtain the higher velocities in the condenser tubes; and one 2" connection to the con-

denser pump, the pump discharging through an 1-1/2" pipe to the rectangular tanks. After making these connections, 7 - 1/2" thermometer holes were bored into the condenser; 4 arranged at equal distances along the top, thermometers at each end, and three along the side at equal distances apart, a thermometer at each end. The thermometer holes in the side were bored to give the thermometers as near an upright postion as possible, all holes being bored tapered to fit rubber corks. It was found necessary to remove a tube from the side of the condenser, because it intefered with the thermometers along the side. Thermometer cups were placed in the condensed steam pipe, near the condenser; in the cooling water outlet, at the condenser; and in the cooling water inlet, a few feet from the condenser.

Next, the apparatus was subjected to a test which showed that it was free from leaks. The condenser was then covered with 1-1/2" of magnesia pipe covering.

The thermometers were calibrated by immersion in water at different temperatures, 10° increments, and the readings of the standard thermometer and the thermometer being calibrated, were taken when the mercury columns became stationary. These calibrations are recorded on pages 13 and 14 ; all correct readings being marked "S" and all numbered readings are those of the calibrated thermometers. The vacuum gauges, a Crosby, No. 500,001 and an ABN. Mercury vacuum gauge, were tested by means of a Crosby Vacuum tester. The results are recorded on page 15.

The scales were calibrated by placing 50 pound Fairbank Standard weights on the scales when the tanks were empty and when they were full. The indicated weight on the scales was noted

before and after each weight was added, 200 pounds being the range used on each scale. The results are shown on page 14, and show the scales to be accurate.

30 minute runs were made, using a constant velocity of cooling water and different pressures in the condenser. The velocity of the water and the supply of steam were regulated by globe valves, the flow of steam being made sufficient to maintain a constant condenser pressure. The condensed steam was pumped to the tanks through a three way valve. The discharge of the cooling water to the tanks, was governed by an elbow and a short piece of pipe, which served the purpose of a three way valve.

The thermometers were placed in the condenser through one hole rubber corks. The thermometer readings were taken at 5 minute intervals, the weight of steam being taken at the same time. The weight of cooling water was taken at 5 minute intervals for the low velocity, but at convenient intervals for the higher velocities, because of the large amount of water to be weighed in the small tanks. A Marsh pump was used for the velocities over 60 feet per minute on account of the great drop in pressure over a meter in the line. The use of the meter for measuring the cooling water was not justifiable, considering the accuracy possible with the apparatus.

The condenser was filled with steam to blow out air pockets and the thermometers were placed in the holes while the steam was still issuing from the holes. Some trials were made without this precaution and running the condenser some time before the taking of readings was commenced; no difference was noted, showing that the air in the condenser was due to that in the steam, the former method being used for this investigation.

A number of difficulties were met with in the course of the experiment which were not foreseen. The thermometers along the top read from 5 to 15 degrees lower than those along the side and the further from the steam inlet, the greater was the drop in the temperature. This was more noticable for the runs using a small quantity of steam. This can be explained by the air collecting at the top of the condenser when there was not sufficient steam condensing to carry it away. This air has a different vapor pressure and it was not mixed with the incoming steam. It was also found that the pump would not give more than a 17" vacuum when the conditions should have given, at least, a 25" vacuum. The cover over the valves was removed, the valve seats were scraped, as were also the valves. The cover was replaced and the pump tried again, with no better results. Accordingly, the hard rubber valves were removed and soft rubber valves substituted. The vacuum went up to 26" with a 29.5" barometer. The pump gave good service for the next two runs, after which the vacuum was noticed to be dropping. The valves were removed again and a small piece of hard rubber was found underneath one of the valves, this was removed, the valves replaced, and the pump tried again with no noticeable improvement. Next, the springs over the valves were loosened and the pump tried again, with the result of a lower vacuum. The cylinder head was removed and the plunger was very loose. A new form of packing was sought, but our efforts failed. It was noticed when the quantity of steam passing through the pump was sufficient to keep the plunger packing wet, there was no trouble with the vacuum. Accordingly, a 1/4" connection into the condensed steam pipe was made from the condensed steam weighing tank. With this connection, it was possible to use the same

[illegible]

[illegible]

[illegible] removed. This was [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

ned, so were also the valves. [illegible]

ing holes which [illegible] to [illegible]

[illegible] valves were removed and [illegible]

The valves were [illegible]

good service for the [illegible] days. [illegible]

[illegible] in by dropping. [illegible]

[illegible] of [illegible] rubber was [illegible]

was reduced, the valves replaced, [illegible]

no noticeable improvement. Later, the [illegible]

loosened and the [illegible]

vacuum. The cylinder head was removed and the [illegible]

loose. A new form of packing was [illegible]

It was noticed when the quantity of [illegible]

was not sufficient to keep the [illegible]

trouble with the vacuum. [illegible]

[illegible]

water over and over again. Using this connection, there was no further trouble with the vacuum.

The thermometer readings were averaged for the run and the average corrected. The results marked "average" are the former and the results marked "Cor. Av." are the latter. The corrected averages are used in all calculations. The average vacuum is usedsince the correction to the ABN gauge was made before recording the reading. The readings for vacuums greater than 17" were taken from the ABN gauge, which is divided into 1/10". It was found to read 1" low upon calibration, the Crosby gauge was correct. All scales were found to be correct, so no correction is applied to the results. The results of the weighing are found on the sheets marked,"Weight of cooling water and condensed steam". The rate of flow of the cooling water, is the net rate, divided by the time between observations of the weights. This rate in pounds per minute, divided by the weight of one cubic foot of water at the temperature of the cooling water discharge, gives the cubic feet per minute. There are two sets of tubes, each containing a different number which necessitates the use of an average velocity. The area of one tube is .00136 sq. ft, which gives an area of .0714 sq. ft. and an area of .091 sq. ft. for the lower set. Dividing the number of cu. ft. per minute by each area and taking the average of both results, gives the average velocity through the tubes. The steam calculations are carried out in the similar manner. The absolute pressure in the condenser is obtained by subtracting the reading of the vacuum gauge from the barometer reading and multiplying by .4908, the equivalent of 1" Mercury in pounds per sq. in. The average temperature in the con-

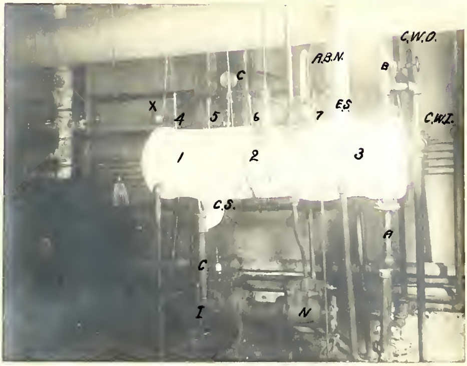
denser is an average of the corrected averages of the seven thermometers in the condenser. The temperature corresponding to the pressure in the condenser, is taken from Peabody's Steam Tables. The rise in temperature of the cooling water, is the difference in the average inlet and outlet cooling water. The total B.T.U. transmitted, per hour, equals the total weight of water per hour multiplied by the rise in temperature of the cooling water.

The total surface of the tubes is computed in two ways, using the inside area which is that exposed to the cooling water, and the outside area which is that exposed to the condensing steam. The inside circumference and the outside circumference multiplied by the length of the tube gives the surfacesof the inside and the outside of the tubes. These areas of one tube multiplied by the total number of tubes, 113, gives 71.05 sq. ft. for the inside area and 91.4 sq. ft. for the outside surface. The mean temperature difference corresponding to the average temperature in the condenser, inside area and outside area, is obtained from the algebraic formula for small condensers, T,M.T.D., = $T_s - \frac{T_1 + T_2}{2}$, where T_s = the temperature in the condenser and T_1 = the inlet cooling water temperature and T_2 is the temperature of the outlet cooling water. The mean temperature difference, corresponding to the pressure in the condenser, is computed as above, T_s being the temperature in the condenser due to the vacuum.

The heat transmitted per degree difference in temperature , per sq. ft., per hour is the total heat per hour divided by the product of the surface, in sq. ft., and the degrees difference in temperature. Four calculations were made, using the inside and outside surface with the actual difference in temperature and with that corresponding to the condenser pressure. These results are in B.T.U. per hour.

The curves are plotted with the rate of heat transmission as ordinates and with the velocity of cooling water in the tubes as abscissa. There were not enough runs to draw a complete curve, but there seems to be a tendency for the rate to increase faster than the velocity. The curve for the 20 inch vacuum shows a maximum velocity. These results show that there is a maximum velocity of cooling water at which the transmission of heat will be greatest. The results show that this maximum velocity depends to a small extent, at least, on the pressure in the condenser. The results of this investigation were carefully computed from data which was taken as described above. The one condition which could not be obtained, constant, was the temperature of the inlet cooling water. The necessity of using the water from the sump, gave an inlet temperature which varied several degrees. Some runs were made with an inlet temperature much higher than the run for the same pressure in the condenser, and a lower velocity. This may be the cause of the difference in the heat transmission for different velocities, at the higher vacuum, and thus, give the curve a maximum velocity. It will be noticed that the cooling water outlet was nearly the same temperature as the condenser, in two of the runs. These conditions are not considered in the plotting of the curves, other, than they effect the actual heat transmission. No allowance was made for radiation from the condenser and all the runs were made using steam from live steam mains, which had a quality of about 97 %.

The cut on this page, shows the condenser with the thermometers and gauges attached. The numbers on the thermometers correspond to those on the recorded data. The thermometer marked C.S. is the one corresponding to Cond. steam on the data sheets. C.W.I. and C.W.O. are the cooling water inlet and outlet. ABN in cut, shows the mercury gauge and C shows the Crosby vacuum gauge. The gauge marked X is a pressure gauge on the cooling water chamber at the rear end of the condenser. In no case, did the pressure exceed 28 pounds. "ES" is the exhaust steam inlet, live steam in



this case, C is the condensed steam, A is the cooling water inlet, and B is the cooling water outlet. The water meter is marked "M". "N" is the Marsh Tank Pump and "I" is the 1/4" connection from the condensed staem tank, to supply water to seal the plunger packing. For all runs, the thermometer marked XII. was used for the cooling water inlet.

Thermometer I. was used at 1 on the condenser for the1st. five runs,X was used for the balance of the runs. II. was used at 2 in the condenser for all runs. III.,VI. , and VIII. were used at 3, 5, and 7 in the condenser. For the first three runs, IV. was used

and VII. for the last 11 runs. IX. was used at 6 in the condenser for all runs. X. was used in the condensed steam for the first five runs and XI. was used for the balance. For the first five runs, XL. was used in the cooling water outlet, for the last 9, the standard thermometer was used.

The cut on this page, shows the tanks, 1 and 2, for the cooling water and the scales and tanks for the condensed steam. Cut No. 3 on this page, shows the Marsh pump and the other side of the cooling water, weighing tanks.

Bibliography.

Engineering.

60 : 146 - 147.
60 : 448
60 : 687
61 : 96
63 : 331 , 341.
67 : 661
70 : 547 , 684
73 : 435

Engineer.

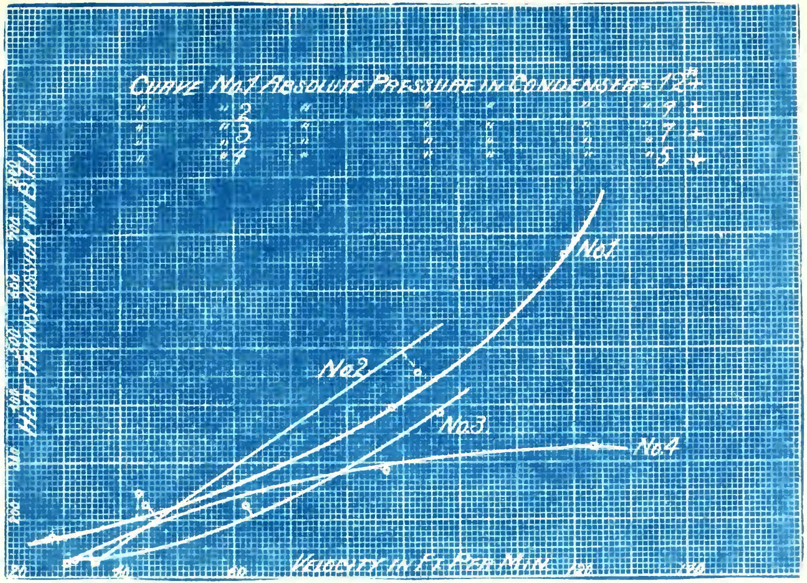
41 : 221

Engineer(London).

83 : 552
84 : 158
84 : 609
87 : 432, 442.
88 : 47
96 : 547, 576.

Power.

May 1897 : 16
Aug. 1899 : 8, 16.
Sept. 1899 : 8, 19.
1903 : 304
June 1901 : 15
April 1902 : 8 (Good)
June 1902 : 30.


CURVE No.1 ABSOLUTE PRESSURE IN CONDENSER = 12 lb +
" " 2 " " " " " 9 +
" " 3 " " " " " 7 +
" " 4 " " " " " 5 +
No.1
No.2
No.3
No.4
HEAT TRANSMISSION IN B.T.U.
100
200
300
400
500
600
700
800
VELOCITY IN FT PER MIN
20
40
60
120
140

Thermometer - Corrections.

Standard Thermometer - Schaeffer & B'Denberg, N.Y. & Chicago.
0° - 100° C. Scale divisions - 1/4°C. Recorded Results - Fahr.°

S.	I.	S.	II.	S.	III.	S.	IV.
54.9	51.0	54.9	55.5	54.9	55.0		
68.0	69.2	68.0	69.0	68.0	69.2	68.1	70.0
87.4	88.9	87.3	88.5	87.3	88.7		
95.4	96.7	95.4	96.8	95.0	96.4	94.7	96.4
105.4	106.7	105.0	106.5	105.1	106.1	105.0	106.5
116.2	117.4	117.2	118.4	115.9	117.3	116.6	118.4
126.8	128.0	125.8	127.2	128.3	129.0	125.4	126.1
139.1	140.0	139.5	140.5	138.6	139.8	140.2	141.2
149.4	149.5	149.6	148.6	151.0	151.8	145.6	146.6
155.0	155.6	158.4	159.0	157.5	158.5	162.0	164.5
179.3	179.5	175.1	175.3	174.2	174.7	177.5	178.2
		185.9	183.5	183.2	183.5		
		197.6	194.0	198.5	197.5		

S.	VI.	S.	VII.	S.	VIII.	S.	IX.
54.9	55.0	54.9	55.7	55.3	56.6	55.0	55.5
68.1	69.0	67.9	69.0	68.0	69.4	68.1	69.1
87.3	88.0	87.3	88.0	87.0	88.4	87.2	88.8
94.6	95.6	94.5	95.5	94.5	95.8	94.2	95.8
104.8	105.8	109.4	110.8	104 .4	105.8	105.5	107.4
116.3	117.0	115.0	116.0	115.7	116.9	117.5	119.1
125.8	127.2	125.0	126.0	128.6	129.5	127.4	128.8
141.2	141.6	136.4	133.5	140.9	141.3	139.1	140.5
148.1	148.2	143.6	144.2	147.4	147.9	149.5	150.1
157.6	156.8	154.1	154.8	158.9	159.0	157.0	157.2
173.0	172.9	161.0	161.8	177.0	176.9	178.3	178.8
195.5	194.6	174.6	175.5	180.3	130.0	178.2	178.8
		190.4	191.0				
200.0	200.0	199.0	200.0	202.1	202.0	201.6	202.0

Thermometer - Corrections (con.).

S.	X.	S.	XI.	S.	XII.
55.0	55.5	54.9	56.9	55.1	56.1
68.0	69.0	68.0	69.4	68.0	69.2
86.9	88.0	86.9	88.2	86.9	88.1
94.5	95.8	95.0	96.6	94.3	95.7
104.5	105.8	104.4	106.0	109.1	110.8
115.3	116.5	117.5	119.1	115.7	117.0
128.7	130.5	126.3	127.9	125.1	126.9
140.5	141.0			136.8	138.0
146.0	146.5			144.0	145.0
159.5	159.6			153.5	154.0
176.0	175.5			163.6	163.0
186.5	186.0	181.8	181.0	175.6	176.0
196.7	196.2	200.2	200.5	192.1	193.0
				197.6	198.0

Calibration of Weighing Scales.

	Tank No.1.		Tank No. 2.	
Wt. on scales.lbs....	555.75	1351.5	544.25	1591.5
" " " + 50-lbs.	604.75	1401.5	594.25	1641.5
" " " +100- ".	654.50	1451.25	644.25	1691.5
" " "+ 150- ".	704.5	1501.5	694.5	1741.75
" " " + 200- ".	754.5	1551.5	744.25	1791.5
Sensative to	1/4	1/2	1/4	1/2

	Scales, No. 5.		Scales, No. 2.	
Wt. on Scales, Lbs...	301.00	1040.0	370.75	1109.25
" " " + 50-lbs.	350.75	1090.5	321.00	1159.5
" " " + 100- ".	401.0	1140.5	371.0	1209.5
" " " + 150- "..	451.0	1190.5	420.75	1259.5
" " " + 200- "..	501.0	1240.25	471.0	1309.5
Sensative to	1/4 - 1/2		1/2 - 3/4	

Calibration of Vacuum Gauges.

S = Mercury Column on Gauge Tester.

G = Crosby Gauge, No. 500,001

ABN = the mercury Gauge.

1.

S	G
28.0	27.8
27.5	27.0
26.0	26.7
26.0	25.9
25.0	24.8
24.0	24.0
23.0	22.9
22.0	22.0
21.0	21.0
20.0	20.1
19.0	19.0
18.0	18.2
17.0	17.0
16.0	16.0
15.0	15.1
14.0	14.6
12.9	13.0
12.0	11.9
11.0	11.0
10.0	10.0
9.0	9.0
8.0	8.1
7.0	7.0

S	ABN
25.0	26.0
24.0	25.15
23.0	24.05
21.0	22.0
20.0	21.05
19.0	20.05
18.0	19.0
17.0	18.0

S (1 - con.)	G
6.0	6.2
4.75	4.8
4.0	4.2
3.0	3.2

25.0	25.0
24.0	24.0
23.0	22.8
22.0	22.1
21.0	21.0
20.0	20.2
19.0	18.9
18.0	18.2
17.0	17.0
12.0	12.0
8.0	8.1

Time	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2:14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2:19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2:24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2:29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2:34	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2:39	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2:44	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
erage	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
. Av.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3:21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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3:36	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3:41	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3:46	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3:51	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
erage	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
. Av.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9:35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9:40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9:45	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9:50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9:55	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10:00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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erage	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
. Av.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Temperatures - °F.

Time	1	2	3	4	5	6	7	Cond. Steam	Cooling water Inlet	Cooling water Outlet	Room.	Barometer in. Hg.	Cond. Vacuum. In. Hg.
		Run 1.			May 9, 1906.								
2:14	186.8	191.5	192.0	179.0	175.0	176.5	176.5	195.5	50.0	155.0	84.0	29.31	4.6
2:19	186.5	191.0	190.5	180.0	173.5	174.0	175.0	194.5	50.0	154.0	84.0	29.31	5.0
2:24	185.0	189.5	191.0	177.5	173.0	175.0	175.0	195.2	49.5	154.5	84.0	29.31	5.0
2:29	185.5	190.5	191.5	179.0	174.0	175.0	176.5	195.0	49.7	154.7	84.0	29.31	4.8
2:34	186.5	189.5	191.0	179.0	172.8	175.5	175.0	195.5	49.5	158.0	84.0	29.31	5.1
2:39	187.5	191.0	191.5	183.0	177.0	178.0	179.0	195.0	49.5	155.0	84.0	29.31	4.5
2:44	186.5	191.5	192.0	182.5	176.6	178.5	179.0	195.0	49.5	155.0	84.0	29.31	4.9
Average	186.3	190.6	191.3	180.0	173.0	176.1	176.6	195.1	49.7	155.9	84.0	29.31	4.8
or. Av.	185.9	193.6	190.7	179.3	173.2	176.1	176.1	195.6	48.7	154.3	84.0	29.31	4.8
		Run 2.			May 9, 1906.								
3:21	134.0	156.0	163.0	122.0	124.7	124.2	123.5	172.5	49.5	102.0	84.0	29.31	9.9
3:26	132.0	155.0	162.0	120.5	123.0	123.0	121.0	171.0	49.2	100.5	84.0	29.31	9.9
3:31	131.0	153.0	160.0	119.0	120.0	121.0	118.5	170.0	49.0	99.0	84.0	29.31	9.8
3:36	128.0	157.5	161.0	116.0	118.0	119.5	115.5	169.7	49.0	96.2	84.0	29.31	9.8
3:41	131.6	151.0	161.0	115.0	118.2	120.0	115.5	170.0	49.0	97.2	84.0	29.31	9.9
3:46	124.0	149.0	160.0	113.5	116.0	119.0	115.5	169.0	49.0	96.0	84.0	29.31	9.9
3:51	124.0	148.0	159.0	112.5	114.5	118.0	115.5	169.0	49.0	96.0	84.0	29.31	10.0
Average	129.1	151.9	160.1	116.9	119.2	120.6	117.8	170.2	49.0	98.8	84.0	29.31	9.9
or. Av.	129.1	150.9	159.1	115.1	118.5	119.5	116.2	170.6	48.0	97.2	84.0	29.31	9.9
		Run 3.			May 11, 1906.								
9:35	157.0	157.0	170.0	137.0	146.5	145.0	141.0	166.5	48.8	116.0	86.0	29.27	15.5
9:40	153.0	158.0	171.0	138.0	145.0	142.0	140.0	167.0	48.8	116.0	86.0	29.27	15.3
9:45	149.0	155.0	170.5	132.2	139.0	137.0	135.0	165.0	48.8	112.0	86.0	29.27	15.3
9:50	147.0	154.0	170.0	130.0	137.0	134.0	136.5	165.5	48.8	111.2	86.5	29.27	15.3
9:55	145.0	152.0	168.5	129.1	134.0	131.8	134.5	165.5	48.8	109.5	86.2	29.27	15.0
10:00	140.5	150.0	167.2	127.0	131.0	129.0	133.0	166.0	48.8	107.5	87.0	29.27	14.6
10:05	143.0	151.0	167.0	127.0	129.8	127.0	133.0	166.5	48.8	107.5	87.3	29.27	14.2
verage	147.8	154.0	169.2	131.4	137.4	135.4	136.1	166.0	48.8	111.4	86.4	29.27	14.98
or. Av.	147.8	153.2	168.6	131.0	136.5	135.4	135.3	166.0	48.5	109.7	86.2	29.27	14.98

Weight of Cooling water and Steam.

Run 1. Cooling Water. May 9,1906.

Time	Tank No.	Gross Wt.	Net Wt.	Lbs. per min.	Cu. Ft. per min.	Av. Vel. per min. in tubes.
3:14	1	555.5	0			
3:22	1	1871.0	1315.5	164.5	2.69	32.0
3:22	2	542.0	0			
3:32	2	1876.5	1334.5	133.45	2.184	26.3
3:32	1	555.0	0			
	1	1827.0	1272.0			
	2	542.5	0			
3:44	2	969.0	427.5	141.5	2.31	28.0
Average for 30 min.			4348.5	144.95	2.368	28.2

Condensed Steam.

Time	Tank-No.	Gross Wt.	Net-Wt.	Lbs. per min.
3:14	2'	380.0		
3:20	2'	488.5	108.5	18.08
3:29	2'	650.0	161.5	17.94
3:39	2'	820.0	170.0	17.0
3:44	2'	895.0	75.0	12.5
30 min.-Av.			515.0	17.16

Weights of Cooling water and Steam.

Run. 2. Cooling water. May 9, 1906.

Time	Tank No.	Gross Wt.	Net Wt.	Lbs. per min.	Cu. Ft. per min.	Av. Vel. per min. in tubes.
3:21	2	540.0	0			
3:27	2	1580.0	1040.0	173.3	2.79	33.52
	2	1911.5	331.5			
	1	555.0	0			
3:33	1	1300.0	745.0	179.4	2.89	34.2
3:36	1	1846.0	546.0	182.6	2.93	35.2
3:36	2	575.0	0			
3:42	2	1586.0	1011.0	168.5	2.72	32.7
3:44	2	1868.0	382.0			
3:44	1	558.0	0			
3:48	1	1476.0	918.0	216.6	3.47	41.7
	1	1759.0	283.0			
	2	663.0	0			
3:51	2	930.0	267.0	183.0	2.945	35.4
30 min.- Av.			5523.0	184.1	2.95	35.5

Condensed Steam.

	Scales.			
3:21	2	301.0	0	
3:34	2	410.0	109.0	8.4
3:39	2	452.25	42.5	8.45
3:46	2	509.0	46.75	8.09
3:51	2	551.0	42.0	8.4
30 min.- Av.			250.0	8.33

Weight of Cooling Water and Steam.

Run 3. Cooling Water. May 11, 1906.

Time	Tank NO.	Gross Wt.	Net Wt.	Lbs. per min.	Cu. Ft. per min.	Av. Vel. per min. in tubes.
9:35	2	538.0	0			
9:39	2	1166.0	628.0	155.0	2.50	30.0
9:43	2	1815.0	747.0	186.0	3.00	36.1
9:43	1	554.0	0			
9:48	1	1356.0	802.0	150.0	2.42	29.1
9:50	1	1657.0	301.0	150.0	2.42	29.1
9:50	2	556.0	0			
9:54	2	1198.0	642.0	158.0	2.54	30.5
9:57	2	1668.0	470.0	156.0	2.51	30.2
9:57	1	559.0	0			
10:02	1	1371.0	812.0	162.0	2.61	31.4
10:02	2	633.5	0			
10:05	2	1110.0	476.5	155.0	2.50	30.1
30 min.- Av.			4880.5	162.6	2.62	31.8

Condensed steam.

	Scales.			
9:35	2	311.0	0	
9:41	2	373.5	62.5	10.4
9:45	2	413.5	40.0	10.0
9:51	2	469.0	55.5	9.2
9:55	2	507.5	35.5	9.6
10:00	2	554.5	47.0	9.4
10:05	2	599.5	45.0	9.0
30 min.- Av.			288.5	9.6

Time	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2:11	[illegible]	[illegible]		[illegible]	[illegible]
2:16	[illegible]	[illegible]		[illegible]	[illegible]
2:21	[illegible]	[illegible]		[illegible]	[illegible]
2:26	[illegible]	[illegible]		[illegible]	[illegible]
2:31	[illegible]	[illegible]		[illegible]	[illegible]
2:36	[illegible]	[illegible]		[illegible]	[illegible]
2:41	[illegible]	[illegible]		[illegible]	[illegible]
rage	[illegible]	[illegible]		[illegible]	[illegible]
Av.	[illegible]	[illegible]		[illegible]	[illegible]
10:5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10:5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11:0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11:0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11:1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11:1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11:2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
rage	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Av.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11:3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11:3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11:4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11:4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11:5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11:5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12:0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
rage	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Av.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

					Temperatures - °F.								
	Run 4.				May 11, 1906.			Cond. Steam	Cooling Water Inlet	Cooling Water Outlet	Room	Barometer In. Hg.	Cond. Vacuum. In. Hg.
Time	1.	2.	3.	4.	5.	6.	7.						
2:11	150.5	146.0	162.5	131.5	137.0	137.0	135.0	161.0	49.0	115.5		29.30	17.2
2:16	102.0	113.0	132.0	106.0	102.0	101.5	126.0	139.0	49.0	80.0		29.30	18.0
2:21	106.5	104.0	146.5	111.0	119.0	119.0	123.5	153.0	49.0	93.5		29.30	18.6
2:26	129.0	126.5	152.0	112.0	117.0	115.0	124.0	155.0	49.0	102.0		29.30	17.8
2:31	92.0	107.0	134.0	98.0	104.0	98.0	114.0	135.0	49.0	81.5		29.30	18.6
2:36	117.0	120.0	151.0	110.0	115.0	114.0	120.0	153.0	49.0	96.0		29.30	18.4
2:41	117.0	117.0	147.0	107.0	111.2	109.0	112.0	152.5	49.0	96.0		29.30	17.9
verage	116.2	120.5	146.4	110.8	115.0	114.8	120.6	149.8	49.0	94.9		29.30	17.92
or. Av.	118.2	119.6	146.0	110.4	114.6	114.7	119.6	149.3	48.0	93.3		29.30	17.92
	Run 5.				May 17, 1906.								
10:51	201.0	201.0	203.0	200.0	199.5	197.5	199.0	201.0	83.0	177.2	88.3	29.50	4.5
10:56	200.5	201.0	202.0	199.6	199.2	202.0	198.5	202.0	84.2	177.4	88.3	29.50	4.5
11:01	199.0	200.5	202.5	198.0	198.0	195.8	198.0	201.0	86.2	177.4	88.3	29.50	4.5
11:06	198.5	200.0	202.2	197.0	197.0	195.0	197.0	201.0	87.0	177.8	88.3	29.50	4.6
11:11	199.0	201.0	202.5	198.0	198.0	196.5	198.0	202.0	96.0	179.6	88.3	29.50	4.5
11:16	199.0	200.5	202.0	197.0	197.0	196.5	197.0	201.2	101.0	179.6	88.3	29.50	4.5
11:21	198.0	200.0	202.0	197.0	196.5	195.0	196.5	201.0	103.5	179.1	88.3	29.50	4.5
erage	199.3	200.6	202.6	198.1	198.0	197.9	197.7	201.7	91.5	178.3	88.3	29.50	4.5
or. Av.	199.8	202.9	203.6	197.1	197.6	198.5	197.9	201.5	90.1	178.3	88.3	29.50	4.5
	Run 6.				May 17, 1906.								
11:30	184.5	188.0	189.5	182.0	182.5	182.5	184.0	190.0	114.5	173.3	95.0	29.60	10.0
11:35	180.0	187.0	188.5	180.0	180.5	181.2	181.0	188.4	117.0	162.0	95.0	29.60	10.0
11:40	179.0	187.0	188.5	177.0	178.5	179.5	180.0	188.4	118.0	164.7	97.0	29.60	10.0
11:45	178.0	185.0	187.5	176.0	178.0	178.0	178.0	187.8	120.5	164.0	98.0	29.60	10.0
11:50	176.0	182.5	186.0	172.0	175.0	175.2	176.5	186.5	123.0	163.4	100.0	29.60	10.0
11:55	178.0	183.0	186.0	173.0	175.5	175.0	177.0	187.0	125.0	165.2	101.0	29.60	10.0
12:00	176.0	185.5	187.0	175.0	178.0	176.8	178.0	188.5	127.5	166.0	101.0	29.60	10.0
verage	178.8	185.7	187.6	177.4	178.3	179.3	179.2	188.1	120.8	165.7	98.1	29.60	10.0
or. Av.	179.3	187.3	188.1	176.4	177.8	179.4	179.3	188.7	119.3	165.7	98.1	29.60	10.0

Weight of Cooling Water and Steam.

Run 4. Cooling Water. May 11, 1906.

Time	Tank. No.	Gross Wt.	Net Wt.	Lbs. per min.	Cu. ft. per min.	Av. Vel. per min. in tubes.
2:11	1	575.0	0			
2:15	1	1192.0	617.0	154.0	2.48	29.9
2:18	1	1653.0	461.0	154.0	2.48	29.9
2:18	2	544.0	0			
2:23	2	1328.0	784.0	157.0	2.53	30.4
2:26	2	1803.0	495.0	165.0	2.66	31.9
2:26	1	551.0	0			
2:30	1	1188.0	637.0	157.0	2.53	30.4
2:33	1	1658.0	470.0	156.0	2.51	30.3
2:33	2	548.0	0			
2:39	2	1500.0	952.0	158.0	2.54	30.5
2:39	1	553.0	0			
2:41	1	869.0	316.0	158.0	2.84	30.5
30 min.- Av.			4731.0	157.7	2.54	30.5

Condensed Steam.

	Scales			
2:11	5	292.0	0	
2:16	5	331.0	39.0	7.8
2:21	5	350.0	19.0	4.8
2:25	5	383.0	33.0	8.2
2:31	5	422.0	39.0	6.5
2:35	5	441.0	19.0	4.9
2:41	5	487.5	46.5	7.7
30 min.- Av.			195.5	6.51

Weight of Cooling Water and Steam.

Run 5. Cooling Water. May 17, 1906.

Time	Tank No.	Gross Wt.	Net Wt.	Lbs. per min.	Cu. ft. per min.	Av. Vel. per min. in tubes.
10:51	1	557.0	0			
10:56	1	1756.0	1201.0	241.0	3.98	47.5
10:56	2	576.0	0			
11:02	2	1856.0	1280.0	213.0	3.52	42.0
11:02	1	556.0	0			
11:09	1	1855.0	1299.0	185.5	3.06	36.5
11:09	2	561.0	0			
11:14	2	1822.0	1261.0	252.0	4.16	49.5
11:14	1	557.0	0			
	1	1702.0	1145.0			
	2	750.0	0			
11:21	2	1134.0	384.0	204.0	3.36	40.0
30 min.- Av.			6570.0	219.0	3.62	43.2

Condensed Steam.

	Scales			
10:51	2	301.0	0	
10:56	2	405.0	104.0	20.8
11:01	2	508.0	103.0	20.6
11:06	2	610.0	102.0	20.4
11:11	2	697.5	87.5	17.5
11:16	2	790.0	93.5	18.7
11:21	2	872.4	82.4	16.48
30 min.- Av.			572.4	19.04

Weight of Cooling Water and Steam.

Run 6. Cooling Water. May 17, 1906.

Time	Tank No.	Gross Wt.	Net Wt.	Lbs. per min.	Cu. Ft. per min.	Av. Vel. per min. in tubes.
11:30	2	582.0	0			
11:36	2	1835.0	1253.0	208.8	3.43	41.5
11:36	1	555.0	0			
11:41	1	1818.0	1263.0	252.6	4.15	49.9
11:41	2	565.0	0			
11:47	2	1844.0	1275.0	212.5	3.48	41.8
11:47	1	556.0	0			
11:52	1	1806.0	1252.0	250.4	4.11	49.8
11:52	2	554.0	0			
	2	1766.0	1212.0			
	1	560.0	0			
12:00	1	1081.0	521.0	216.6	3.56	42.8
30 min.- Av.			6776.0	225.8	3.71	44.5

Condensed Steam.

	Scales			
11:30	2	872.4	0	
11:35	2	930.0	57.6	11.5
11:40	2	983.0	53.0	10.6
11:45	2	1033.0	50.0	10.0
11:50	2	1081.0	48.0	9.6
11:55	2	1126.0	45.0	9.0
12:00	2	1173.0	47.0	9.4
30 min.- Av.			300.6	10.02

Time	Run	[illegible]	[illegible]	[illegible]	[illegible]
9:08	1	[illegible]	[illegible]	[illegible]	[illegible]
9:13	1	[illegible]	[illegible]	[illegible]	[illegible]
9:18	1	[illegible]	[illegible]	[illegible]	[illegible]
9:23	1	[illegible]	[illegible]	[illegible]	[illegible]
9:28	1	[illegible]	[illegible]	[illegible]	[illegible]
9:33	1	[illegible]	[illegible]	[illegible]	[illegible]
9:38	1	[illegible]	[illegible]	[illegible]	[illegible]
Average	1	[illegible]	[illegible]	[illegible]	[illegible]
Av.	1	[illegible]	[illegible]	[illegible]	[illegible]
	Ru				
0:06	1	[illegible]	[illegible]	[illegible]	[illegible]
0:11	1	[illegible]	[illegible]	[illegible]	[illegible]
0:16	1	[illegible]	[illegible]	[illegible]	[illegible]
0:21	1	[illegible]	[illegible]	[illegible]	[illegible]
0:26	1	[illegible]	[illegible]	[illegible]	[illegible]
0:31	1	[illegible]	[illegible]	[illegible]	[illegible]
0:36	1	[illegible]	[illegible]	[illegible]	[illegible]
age	1	[illegible]	[illegible]	[illegible]	[illegible]
Av.	1	[illegible]	[illegible]	[illegible]	[illegible]
	Ru				
0:52	1	[illegible]	[illegible]	[illegible]	[illegible]
0:57	1	[illegible]	[illegible]	[illegible]	[illegible]
1:02	1	8.2	[illegible]	[illegible]	[illegible]
1:07	1	[illegible]	[illegible]	[illegible]	[illegible]
1:12	1	[illegible]	[illegible]	[illegible]	[illegible]
1:17	1	[illegible]	[illegible]	[illegible]	[illegible]
1:22	1	[illegible]	[illegible]	[illegible]	[illegible]
age	1	[illegible]	[illegible]	[illegible]	[illegible]
Av.	1	[illegible]	[illegible]	[illegible]	[illegible]

Time	Temperatures - °F. 1	2	3	4	5	6	7	Cond. Steam	Cooling Inlet	Water Outlet	Barometer In. Hg.	Cond. Vacuum. In. Hg.
Run 7.				May 25, 1906.								
9:08	164.0	167.0	169.0	152.0	161.0	156.0	161.0	176.3	92.0	131.0	29.45	14.75
9:13	163.0	165.5	168.5	150.0	158.0	153.0	158.0	170.0	94.0	131.9	29.45	15.2
9:18	163.0	165.5	167.0	151.0	157.0	153.0	158.0	170.0	95.5	133.7	29.45	15.2
9:23	164.0	167.0	168.0	152.0	158.0	154.0	158.0	171.0	98.0	136.0	29.45	15.0
9:28	165.0	168.0	171.0	153.5	158.2	154.0	158.0	171.6	101.0	137.3	29.45	14.9
9:33	164.0	165.5	170.0	150.0	155.0	151.0	156.0	170.6	103.6	136.7	29.45	15.0
9:38	166.0	166.6	169.0	151.0	157.0	153.0	157.0	171.5	106.0	140.0	29.45	14.7
Average	164.1	166.4	168.9	151.3	157.7	153.4	158.0	170.7	98.5	135.1	29.45	14.96
r. Av.	164.3	165.8	168.3	150.6	157.2	154.2	158.9	170.0	98.1	135.1	29.45	14.96
Run 8.				May 25, 1906.								
10:06	195.0	195.0	197.0	190.5	193.0	188.0	187.0	196.0	116.0	167.4	29.45	6.2
10:11	195.0	196.0	197.0	192.0	194.0	190.0	191.0	199.5	120.0	169.0	29.45	4.5
10:16	198.0	200.0	200.0	197.0	198.0	194.5	194.5	202.2	125.0	175.5	29.45	3.5
10:21	195.0	197.0	197.0	194.0	195.0	192.0	192.0	200.0	131.0	175.1	29.45	4.2
10:26	195.0	198.0	197.0	194.0	194.2	191.0	190.0	199.0	135.5	176.4	29.45	4.7
10:31	195.0	197.5	197.5	193.5	194.0	191.5	191.3	199.0	140.0	178.7	29.45	4.9
10:36	195.0	198.0	198.0	193.0	193.7	191.5	191.0	199.0	145.0	179.6	29.45	4.8
erage	195.4	197.3	197.6	193.4	194.5	191.2	190.9	198.9	130.3	174.8	29.45	4.68
r. Av.	195.9	200.9	198.6	192.8	194.1	192.1	190.9	198.0	128.8	174.8	29.45	4.68
Run 9.				May 25, 1906.								
10:52	174.0	176.0	181.5	172.5	175.0	172.0	176.0	182.5	151.5	167.0	29.45	10.7
10:57	180.0	181.5	184.0	175.0	176.5	174.0	177.0	186.5	152.0	169.7	29.45	10.0
11:02	179.0	182.0	186.0	175.5	177.0	174.5	176.6	187.0	153.0	171.0	29.45	9.8
11:07	176.0	179.8	184.6	174.0	175.5	173.5	175.5	187.0	154.0	170.6	29.45	9.75
11:12	177.0	179.0	184.6	174.0	175.5	173.0	175.6	185.8	154.5	170.6	29.45	10.0
11:17	176.0	179.0	184.5	174.0	175.0	173.0	175.0	185.5	155.0	170.8	29.45	10.0
11:22	178.0	179.5	184.0	175.2	175.0	173.2	175.0	186.0	156.0	171.5	29.45	10.0
erage	177.1	175.2	184.2	174.3	175.5	173.3	175.7	186.5	153.7	170.3	29.45	10.0
r. Av.	177.6	175.0	183.9	173.1	175.0	173.4	175.8	187.3	153.2	170.3	29.45	10.0

Weight of Cooling Water and Steam.

Run 7. Cooling Water. May 23, 1906.

Time	Tank No.	Gross Wt.	Net Wt.	Lbs. per min.	Cu. Ft. per min.	Av. Vel. per min. in tubes.
9:08	1	561	0			
9:11	1	1572	1011	337.0	5.5	66.2
9:11	2	582	0			
9:14	2	1535	953	318.0	5.18	62.4
9:14	1	551	0			
9:17	1	1503	952	314	5.11	61.5
9:17	2	597	0			
9:20	2	1569	972	324	5.26	63.6
9:20	1	535	0			
9:23	1	1468	933	311	5.06	6.9
9:23	2	698	0			
9:26	2	1644	956	318	5.18	62.4
9:26	1	535	0			
9:29	1	1481	946	315	5.41	61.9
9:29	2	658	0			
9:32	2	1586	928	309	5.04	58.4
9:32	1	569	0			
9:35	1	1501	962	321	5.23	62.9
9:35	2	590	0			
9:38	2	1469	879	293	4.77	57.3
30 min. AV.			9494	316.4	5.15	62.0

Condensed Steam.

	Scales.			
9:08	2	300	0	
9:12	2	353	53	13.2
9:19	2	442	89	12.7
9:24	2	578	56	11.2
9:30	2	580	72	12.0
9:34	2	621	41	10.2
9:38	2	671	50	12.5
30 min.	Av.		371	12.3

Weight of Cooling Water and Steam.

Run 8. Cooling Water. May 23, 1906.

Time	Tank No.	Gross Wt.	Net Wt.	Lbs. per min.	Cu. Ft. per min.	Av. Vel. per min. in tubes.
10:06	1	527	0			
10:08	1	1443	916	458	7.56	90.9
10:08	2	587	0			
10:10	2	1440	853	426	6.86	82.5
10:10	1	552	0			
10:12	1	1407	855	427	6.87	82.6
10:12	2	766	0			
10:14	2	1644	878	439	7.25	87.2
10:14	1	684	0			
10:16	1	1573	889	444	7.33	88.1
10:16	2	730	0			
10:18	2	1620	890	445	7.34	88.2
10:18	1	586	0			
10:20	1	1482	896	448	7.40	89.0
10:20	2	726	0			
10:22	2	1630	904	452	7.45	89.6
10:22	1	592	0			
10:24	1	1500	908	454	7.49	90.0
10:24	2	866	0			
10:26	2	1769	903	452	7.45	89.6
10:26	1	584	0			
10:28	1	1494	910	455	7.5	90.1
10:28	2	745	0			
10:30	2	1652	907	453	7.49	90.0
10:30	1	586	0			
10:32	1	1487	901	450	7.43	89.4
10:32	2	731	0			
10:34	2	1633	902	451	7.43	89.4
10:34	1	577	000			
10:36	1	1435	868	434	7.10	86.2
30 min. Av.			13281	444	7.33	88.1

Condensed Steam.

	Scales			
10:06	2	671	0	
10:11	2	782	111	22.2
10:16	2	901	119	23.8
10:21	2	1017	116	23.2
10:26	2	1118	101	20.2
10:31	2	1211.5	93.5	18.7
10:36	2	1305	92.5	18.5
30 min. Av.			634	21.1

Time	Rur				
10.14	1	[illegible]	[illegible]	[illegible]	[illegible]
10:19	1	[illegible]	[illegible]	[illegible]	[illegible]
10:24	1	[illegible]	[illegible]	[illegible]	[illegible]
10:29	1	[illegible]	[illegible]	[illegible]	[illegible]
10:34	1	[illegible]	[illegible]	[illegible]	[illegible]
10:39	1	[illegible]	[illegible]	[illegible]	[illegible]
10:44	1	[illegible]	[illegible]	[illegible]	[illegible]
erage		[illegible]	[illegible]	[illegible]	[illegible]
r. Av.		[illegible]	[illegible]	[illegible]	[illegible]
	Ru				
2:28		[illegible]	[illegible]	[illegible]	[illegible]
2:33		[illegible]	[illegible]	[illegible]	[illegible]
2:38		[illegible]	[illegible]	[illegible]	[illegible]
2:43		[illegible]	[illegible]	[illegible]	[illegible]
2:46		[illegible]	[illegible]	[illegible]	[illegible]
erage		[illegible]	[illegible]	[illegible]	[illegible]
r. Av.		[illegible]	[illegible]	[illegible]	[illegible]

Temperatures - °F.

Time	1	2	3	4	5	6	7	Cond. Steam	Cooling Water Inlet	Cooling Water Outlet	Barometer In. Hg.	Condenser Vacuum In. Hg.
Run 10.				May 26, 1906.								
10.14	115.5	118.0	134.5	119.0	121.0	118.5	119.5	131.5	101.0	111.8	29.3	22.7
10:19	115.5	115.5	133.0	118.0	120.0	117.5	120.0	128.5	101.5	111.2	29.3	22.5
10:24	116.0	114.0	132.5	117.0	119.0	117.0	119.5	127.0	102.5	111.2	29.3	22.5
10:29	115.6	113.5	132.0	117.0	119.0	117.0	120.0	126.0	104.0	112.1	29.3	22.6
10:34	116.5	114.0	131.5	118.0	119.0	117.5	120.0	125.5	104.5	113.0	29.3	22.5
10:39	116.0	117.0	133.0	118.5	119.0	118.0	120.0	129.0	106.0	115.8	29.3	22.4
10:44	117.0	118.5	133.6	120.0	119.5	119.0	121.0	130.5	107.0	116.0	29.3	22.4
Average	115.8	115.8	132.9	118.2	119.5	117.8	120.0	128.3	103.3	112.8	29.3	22.5
Cor. Av.	114.6	115.0	132.2	117.2	118.0	117.1	119.0	126.7	102.1	112.8	29.3	22.5
Run 11.				May 29, 1906.								
2:28	156.6	150.6	157.0	151.0	154.0	154.0	151.5	158.0	89.0	125.9	29.7	19.0
2:33	150.5	147.0	152.5	146.0	148.0	145.5	148.0	156.0	95.5	124.7	29.7	19.2
2:38	150.5	146.0	153.0	146.0	146.5	145.0	147.0	156.5	98.5	125.6	29.7	19.1
2:43	148.0	145.0	154.0	143.0	144.5	143.0	145.0	156.5	103.0	126.8	29.7	19.2
2:46	150.5	146.0	155.0	143.0	144.5	143.5	145.5	157.0	106.0	126.5	29.7	19.0
Average	151.2	146.9	154.3	145.8	147.5	146.2	147.4	156.8	98.4	125.0	29.7	19.1
Cor. Av.	150.9	145.9	153.4	145.2	146.9	146.1	146.9	156.0	97.0	125.0	29.7	19.1

Weight of Cooling Water and Steam.

Run 10. Cooling Water. May 26, 1906.

Time	Tank No.	Gross Wt.	Net Wt.	Lbs. per min.	Cu. Ft. per min.	Av. Vel. per min. in tubes.
10:14	1	524	0			
10:17	1	1871	1347	449	7.25	87.2
10:17	2	588	0			
10:19	2	1575	987	493	7.25	87.2
10:19	1	546	0			
10:22	1	1915	1369	456	7.35	88.35
10:22	2	625	0			
10:24	2	1870	1245	498	8.05	96.9
10:24	1	680	0			
10:27	1	1920	1240	496	8.0	96.1
10:27	2	691	0			
10:30	2	1975	1284	424	6.84	82.25
10:30	1	560	0			
10:33	1	1925	1365	482	7.78	93.5
10:33	2	608	0			
10:35	2	1649	1041	481	7.76	93.3
10:35	1	580	0			
10:37	1	1588	1008	504	8.12	97.6
10:37	2	666	0			
10:39	2	1584	918	459	7.14	88.9
10:39	1	562	0			
10:41	1	1936	874	437	7.05	84.75
10:41	2	605	0			
10:44	2	1700	1095	365	5.88	70.7
30 min. Av.			13773	459	7.44	89.5

Condensed Steam.

	Scales.			
10:14	2	300	0	
10:19	2	331.5	31.5	6.3
10:23	2	352.0	20.5	5.1
10:28	2	374.0	22.0	4.4
10:33	2	397.0	23.0	4.7
10:38	2	421.0	24.0	4.8
10:44	2	451.0	30.0	5.0
30 min. Av.			151.0	5.03

Weight of Cooling Water and Steam.

Run 11. Cooling Water. May 29, 1906.

Time	Tank No.	Gross Wt.	Net Wt.	Lbs. per min.	Cu. Ft. per min.	Av. Vel. per min. in tubes.
2:28	2	581	0			
2:31	2	1916	1335	448	7.28	87.4
2:31	1	568	0			
2:34	1	1834	1266	422	6.86	82.5
2:34	2	595	0			
2:37	2	1903	1388	462	7.5	85.1
2:37	1	536	0			
2:40	1	1841	1305	435	7.06	84.9
2:40	2	603	0			
2:43	2	1920	1317	439	7.14	85.7
2:43	1	541	0			
2:46	1	1920	1379	459	7.46	89.2
18 min. Av.			7990	444	7.22	86.8

Condensed Steam.

	Scales			
2:28	2	528	0	
2:34	2	618	90	15.0
2:39	2	684	66	13.2
2:45	2	750	66	11.0
2:46	2	761	11	11.0
18 min. Av.			233	12.96

Run

Time				
9:09	[illegible]	[illegible]	[illegible]	[illegible]
9:14	[illegible]	[illegible]	[illegible]	[illegible]
9:19	[illegible]	[illegible]	[illegible]	[illegible]
9:24	[illegible]	[illegible]	[illegible]	[illegible]
9:29	[illegible]	[illegible]	[illegible]	[illegible]
9:34	[illegible]	[illegible]	[illegible]	[illegible]
9:39	[illegible]	[illegible]	[illegible]	[illegible]
age	[illegible]	[illegible]	[illegible]	[illegible]
Av.	[illegible]	[illegible]	[illegible]	[illegible]

Ru

10:27	[illegible]	[illegible]	[illegible]	[illegible]
10:32	[illegible]	[illegible]	[illegible]	[illegible]
10:37	[illegible]	[illegible]	[illegible]	[illegible]
10:42	[illegible]	[illegible]	[illegible]	[illegible]
10:47	[illegible]	[illegible]	[illegible]	[illegible]
10:52	[illegible]	[illegible]	[illegible]	[illegible]
10:57	[illegible]	[illegible]	[illegible]	[illegible]
age	[illegible]	[illegible]	[illegible]	[illegible]
Av.	[illegible]	[illegible]	[illegible]	[illegible]

Ru

11:06	[illegible]	[illegible]	[illegible]	[illegible]
11:11	[illegible]	[illegible]	[illegible]	[illegible]
11:16	[illegible]	[illegible]	[illegible]	[illegible]
11:21	[illegible]	[illegible]	[illegible]	[illegible]
11:26	[illegible]	[illegible]	[illegible]	[illegible]
age	[illegible]	[illegible]	[illegible]	[illegible]
Av.	[illegible]	[illegible]	[illegible]	[illegible]

Temperatures - °F.

Time	1	2	3	4	5	6	7	Cond. Steam.	Cooling Water Inlet	Outlet	Barometer	Cond. Vacuum. In. Hg.
Run 12.					May 31, 1906.							
9:09	173.0	165.0	173.0	166.0	169.3	168.0	164.0	176.0	85.0	134.1	29.05	14.0
9:14	175.0	167.0	173.8	168.0	171.0	168.0	165.0	178.0	89.0	138.4	29.05	13.5
9:19	169.0	163.0	168.0	162.0	164.5	160.0	156.0	173.0	95.0	133.7	29.05	14.4
9:24	165.0	163.0	166.0	158.0	160.4	155.0	153.0	171.0	100.0	133.7	29.05	15.0
9:29	163.5	164.0	166.0	156.0	160.0	154.0	153.0	171.0	105.0	136.4	29.05	15.0
9:34	161.0	162.0	165.0	154.0	156.8	152.0	151.0	170.0	109.0	136.3	29.05	15.2
9:39	163.0	164.5	167.0	156.0	158.0	154.0	154.0	171.5	113.0	140.4	29.05	14.92
Average	167.1	164.0	168.9	160.0	162.9	158.7	156.6	173.0	95.0	137.2	29.05	14.6
or. Av.	166.8	163.6	168.3	159.2	162.7	159.5	156.5	173.8	93.6	137.2	29.05	14.6
Run 13.					May 31, 1906.							
10:27	143.0	138.0	151.5	142.0	149.0	147.0	144.5	151.0	120.0	131.2	29.05	20.35
10:32	147.0	143.5	152.0	143.5	149.0	146.0	144.5	153.8	121.5	134.24	29.05	20.0
10:37	145.0	141.8	154.7	143.0	149.0	145.0	145.0	153.5	123.2	134.8	29.05	20.0
10:42	144.5	142.0	151.8	142.0	148.0	144.5	143.5	154.0	125.5	135.95	29.05	19.95
10:47	145.0	143.0	151.0	142.0	147.0	143.5	143.5	154.0	126.4	136.8	29.05	20.0
10:52	145.0	143.0	151.0	142.8	146.8	144.0	142.5	155.0	128.0	137.75	29.05	20.0
10:57	146.0	143.0	151.2	143.5	146.5	143.5	143.0	155.0	129.0	139.1	29.05	19.8
verage	145.0	143.4	151.8	142.6	147.9	144.8	143.5	153.7	124.4	135.8	29.05	20.0
or. Av.	144.5	142.4	151.1	142.0	147.4	144.7	143.1	153.0	123.1	135.8	29.05	20.0
Run 14.					May 31, 1906.							
11:06	203.0	202.0	203.0	202.5		204.0	202.0	205.5	139.8	187.2	29.05	3.0
11:11	202.0	201.0	203.0	203.5		204.0	202.0	202.0	147.0	187.7	29.05	4.5
11:16	202.0	204.0	203.0	203.0		203.0	202.0	202.5	153.0	190.4	29.05	4.5
11:21	198.0	200.0	201.0	201.0		201.0	200.0	203.0	158.0	189.9	29.05	5.0
11:26	199.0	200.0	201.0	201.0		201.0	200.5	204.0	164.5	191.3	29.05	4.5
verage	200.8	201.0	202.2	201.9		202.6	201.3	203.4	152.4	189.0	29.05	4.3
or. Av.	201.3	204.0	203.2	202.9		202.6	201.3	203.9	151.9	189.0	29.05	4.3

Weight of Cooling Water and Steam.

Run 12. Cooling Water. May 31, 1906.

Time	Tank No.	Gross Wt.	Net Wt.	Lbs. per min.	Cu. Ft. per min.	Av. Vel. per min. in tubes
9:09	1	576				
9:11	1	1482	966	484	7.9	93.5
9:11	2	581				
9:13	2	1524	943	472	7.7	92.8
9:13	1	576				
9:15	1	1546	970	485	7.9	95.4
9:15	2	694				
9:17	2	1646	952	476	7.75	93.5
9:17	1	540				
9:19	1	1521	981	490	7.98	96.7
9:19	2	736				
9:21	2	1728	992	496	8.9	97.4
9:21	1	555				
9:23	1	1575	1020	510	8.31	100.0
9:23	2	634				
9:25	2	1593	959	479	7.81	94.2
9:25	1	589				
9:27	1	1567	978	489	7.96	95.5
9:27	2	694				
9:29	2	1675	981	491	8.0	96.5
9:29	1	555				
9:31	1	1535	980	490	7.98	96.2
9:31	2	655				
9:33	2	1636	981	49~~1~~	8.0	96.5
9:33	1	643				
9:35	1	1629	986	493	8.03	96.8
9:35	2	666				
9:37	2	1672	1006	503	8.2	98.7
9:37	1	558				
9:39	1	1515	957	479	7.8	93.9
30 min. Av.		14652		488.4	7.97	96.4

Condensed Steam.

Time	Scale.			
9:09	2	502		
9:17	2	692	190	23.7
9:22	2	798	106	21.2
9:27	2	885	87	17.4
9:32	2	966	81	16.2
9:37	2	1038	72	14.4
9:39	2	1070	32	16.0
30 min. Av.			568	18.8

Weight of Cooling Water and Steam.

Run 13. Cooling Water. May 31, 1906.

Time	Tank No.	Gross Wt.	Net Wt.	Lbs. per min.	Cu. Ft. per min.	Av. Vel. per min. in tubes.
10:27	1	519	0			
	1	1791	1272			
	2	597	0			
	2	1835	1238			
	1	623	0			
10:33	1	1872	1249	627	10:2	123
10:33	2	700	0			
	2	1894	1194			
	1	595	0			
	1	1903	1308			
	2	770	0			
10:39	2	1920	1150	608	9.92	120
10:39	1	574	0			
	1	1852	1278			
	2	780	0			
	2	1841	1061			
	1	560	0			
10:45	1	1914	1354	615	10.0	120.7
10:45	2	680	0			
	2	1902	1222			
	1	570	0			
	1	1894	1324			
	2	783	0			
10:50	2	1609	814	672	10.9	131.7
10:50	1	768	0			
	1	1874	1106			
	2	840	0			
	2	1921	1081			
	1	667	0			
	1	1898	1231			
	2	818	0			
10:57	2	1775	957	625	10.2	123.0
30 min. Av.			18839	627.9	10.25	123.2

Condensed Steam.

	Scales.			
10:27	2	585	0	
10:32	2	625	40	8.0
10:37	2	668	43	8.6
10:42	2	708	40	8.0
10:47	2	747	39	7.8
10:52	2	786	39	7.8
10:57	2	825	39	7.8
30 min. Av.			240.	8.0

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
V	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
T	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
T	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
I	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
R	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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T	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
M	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
H	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
H	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
H	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
H	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Run,	1	2	3	4	5	6	7.	8.	9.	10.	11.	12.	13	14
Velocity in condenser tubes, average, ft. per min.,	28.2	35.5	31.8	30.5	43.2	44.5	62.00	88.10	92.6	89.5	86.8	96.4	123.2	118.3
Absolute pressure in condenser, lbs. per sq. in.,	12.02	9.54	7.0	5.59	12.3	9.63	7.11	12.66	9.55	3.33	5.2	7.1	4.4	12.15
Average temperature in condenser, °F.,	178.5	129.8	143.9	120.0	199.6	180.6	159.9	195.0	176.3	119.1	147.6	162.4	150.0	202.5
Temperature corresponding to pressure in condenser, °F.,	202.0	191.0	176.9	167.0	203.0	191.5	178.0	204.0	191.0	146.0	164.0	178.0	157.0	202.6
Temperature of condensed steam, °F.,	195.6	170.6	166.0	149.3	201.5	188.7	170.0	198.0	187.3	126.7	156.0	173.8	153.7	203.1
Lbs. of cooling water per hour,	8697.0	11046.0	9761.0	9462.0	13140.0	13552.0	18988.0	26562.0	27664.0	27546.0	26633.0	29304.0	37678.0	35658.0
Rise in temperature of cooling water, °F.,	105.6	49.2	61.2	45.3	88.2	46.4	37.0	46.0	17.1	10.7	28.0	43.6	12.7	37.1
Total B.T.U. transmitted, per hour,	918403	543463	597374	428628	1158948	628813	702556.0	1221852.0	473054.0	294742.0	745724.0	1277654.0	478510.0	1397112.0
Total inside area of tubes, sq. ft.,	71.05	71.05	71.05	71.05	71.05	71.05	71.05	71.05	71.05	71.05	71.05	71.05	71.05	71.05
" outside " " " , sq. ft.,	91.4	91.4	91.4	91.4	91.4	91.4	91.4	91.4	91.4	91.4	91.4	91.4	91.4	91.4
Mean temperature difference, actual, °F.,	76.5	59.2	64.8	49.4	65.4	38.1	43.3	43.2	14.6	11.7	36.6	47.0	20.6	32.1
" " " , corresponding to pressure in cond.,°F.	100.5	118.4	97.8	96.4	68.8	49.0	61.4	52.2	29.3	38.6	53.0	62.6	27.6	32.2
Heat transmitted per degree dif. in temperature, per sq. ft. per hr., actual temperature, inside area, B.T.U.,	169.0	129.0	129.8	123.0	249.0	230.0	227.5	397.8	455.0	354.0	286.5	382.0	326.0	661.0
Heat transmitted per degree dif. in temperature, per sq. ft., per hr., actual temperature, outside area, B.T.U.,	131.5	100.5	101.0	96.0	194.2	179.0	177.1	309.5	353.0	276.0	223.2	297.0	254.0	475.0
Heat transmitted per degree dif. in temperature, per sq. ft., per hr., corresponding to cond. pres., inside area, B.T.U.,	128.5	64.5	86.0	62.5	237.0	180.0	161.1	329.0	227.0	107.4	198.0	349.0	244.0	610.0
Heat transmittion per degree dif. in temperature, per sq. ft., per hr., corresponding to cond. pres., outside area, B.T.U.,	100.3	50.2	67.0	48.7	184.0	140.5	125.0	255.0	177.5	84.0	154.0	272.0	189.5	474.0

R. L. Eason.
R. W. Kimball.